A GIS Approach for the Integration of the Transit Network with the Road Public Transport in the Metropolitan Area of Palermo.

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Object

1. The calibration of a nested logit modal choice model, that simulates the distribution of demand, between the various modes of transport available in a passengers interchange node: Notarbartolo, by using different available data sources;
2. The prediction of the modal choice variation in different scenarios (short and medium term), in which the transport infrastructure landscape will change by introduction of new transport systems (as such as tram and light rail).
Outline

• The nested logit model
• The role of the Notarbartolo Node in transport system of the city
• The specification and the calibration of model
• The application of model in future scenarios
• The short term scenario
• The medium term scenario
• Conclusion
The **nested logit model** has three alternative: car, bus and light rail. The expressions of systematic utility are:

\[
\begin{align*}
W_{\text{car}} &= \beta_1 T_{\text{car}} + \beta_2 C_{\text{car}} + \beta_3 NA + ASA_{\text{car}} \\
W_{\text{bus}} &= \beta_1 T_{\text{bus}} + \beta_4 T_w + \beta_5 NT \\
W_{\text{light rail}} &= \beta_1 T_{\text{light rail}} + ASA_{\text{light rail}} \\
W_{tp} &= \theta \ln \left[ \exp(W_{\text{bus}}) + \exp(W_{\text{light rail}}) \right] + \beta_2 C_{tp}
\end{align*}
\]

**So we have the utility for Public Transport** \( W_{tp} \);

Above the attributes for each alternative are:

**car**
- \( T_{\text{car}} \): travel time;
- \( C_{\text{car}} \): monetary cost;
- \( NA \): number of cars for household;
- \( ASA_{\text{car}} \): specific attributes of the alternative;

**bus**
- \( T_{\text{bus}} \): travel time;
- \( T_w \): waiting time;
- \( NT \): number of bus line transfer;

**light rail**
- \( T_{\text{light}} \): rail travel time;
- \( ASA_{\text{light rail}} \): specific attributes of the alternative;

\( (b_i \text{ are coefficients of the model and } C_{tp} \text{ is the monetary cost}) \)

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The nested logit model

Tree of choice

\[
\theta_o \quad \theta
\]

\[
\begin{align*}
P_{bus} &= P_{bus/TP} \cdot P_{TP} \\
P_{light\ rail} &= P_{light\ rail/TP} \cdot P_{TP} \\
P_{TP} &= \frac{\exp(W_{TP})}{\exp(W_{TP}) + \exp(W_{car})} \\
P_{car} &= \frac{\exp(W_{car})}{\exp(W_{TP}) + \exp(W_{car})} \\
P_{bus/TP} &= \frac{\exp(W_{bus})}{\exp(W_{bus}) + \exp(W_{light\ rail})} \\
P_{light\ rail/TP} &= \frac{\exp(W_{light\ rail})}{\exp(W_{bus}) + \exp(W_{light\ rail})}
\end{align*}
\]
Data sources year 2006

- **DITRA** → Direct survey on modal choice by the submission of questionnaire
- **Census 2001** → Data from zones (residents, imployners)
- **AMAT** → Passengers per year carried by bus
- **Trenitalia** → Daily passengers on rail link Pa C.le - Notarbartolo - Giachery
- **City Council** → Hourly car flows of some road links by loop detectors
- **DITRA** → O/D matrix for car and peak hour update to 2006

*Daily flows of passengers on some O/D relations*

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Palermo

Palermo is one million of inhabitants large centre of attraction for commuters is hence affected by a high number daily trips that have origin or destination in close areas. The metropolitan area is interested by sprawl with low residential density in wide suburban areas of city. In the last years some policy measures for discourage the use of private car were implemented by limited traffic zones, park pricing and eco-pass.
Road transport infrastructures of Palermo
Railway infrastructures of Palermo
Passenger interchange node: Notarbartolo

Actual configuration:

The station is a stop for road public transport, for railway line for intraregional service (Trapani and Castelvetrano), of light rail line for the airport, and also for urban railway ring, giving a possibility to the interchange with the other lines and services to reach any destination. The node is localized within the Central Business District (CBD) and it is a relevant commercial/shopping area. The parking areas near the station allow the interchange between the private car and transit. Further the node is served by five bus lines whose three are inside CBD and two connect peripheral areas.
Passenger interchange node: Notarbartolo

Future configuration:

The station, by the closure of the railway ring and the realization of railway crossing, will became the main intermodal node for passenger that will be crossed by bulk of commuter journeys /trips from and for the city. The station is undertaking a restyling, that will allow a wider surface (about 1000 m²) for commercial spaces, and areas destined to the welcome of the travellers as lounge, waiting, ticketing and so on.
Calibration of a nested logit demand model

The study area has been chosen taking into account all O/D relations reachable by private car, bus and urban light rail. Therefore the user can make a choice between private transport and public transport (bus and light rail). The first step has been to identify all zones of Palermo, where the potential user can access to the light rail service.

Study area
Calibration of a nested logit demand model

The demand model has been calibrated by a generalized least squares minimization method through the following expression:

\[
\beta^* = \arg \min_{\beta \in S_B} \left[ \sum_i \frac{(b_i - \bar{\beta}_i)^2}{\text{var}[\sigma_i]} + \sum_i \frac{(f_{\text{od}} - \sum_i d_{\text{odm}}(b_i))^2}{\text{var}[\epsilon_{\text{od}}]} \right]
\]

where vectors \( \bar{\beta}_i \) and \( f_{\text{od}} \) are initial coefficients and flows for any transport mode (car, bus, light rail) respectively.
Calibration of a nested logit demand model

It should be noted that all coefficients have correct sign and also the model shows a high goodness of fit. The value of time is equal to 3.60 €/h in according to previous estimations and urban planning tools.

Coefficients of calibrated model

<table>
<thead>
<tr>
<th>Coeff.</th>
<th>Value</th>
<th>Param.</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_1$</td>
<td>-0.2</td>
<td>$VOT_{travel}$</td>
<td>3.60 €/h</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>-3.33</td>
<td>$VOT_{waiting}$</td>
<td>6.97 €/h</td>
</tr>
<tr>
<td>$\beta_3$</td>
<td>2.5</td>
<td>$R^2$</td>
<td>0.92</td>
</tr>
<tr>
<td>$ASA_{light,rail}$</td>
<td>-4.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ASA_{car}$</td>
<td>-0.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tau = \theta_1 \theta_0$</td>
<td>0.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_4$</td>
<td>-0.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_5$</td>
<td>-0.2</td>
<td></td>
<td></td>
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</tbody>
</table>
The application of model in future scenarios

The calibrated model has been used to estimate the potential demand of transport in two scenarios.
1. “short term scenario” is characterized by introduction of tram;
2. “medium term scenario” is characterized by closure of railway ring and realization railway crossing.

Scenarios have been designed by the reorganization of road public transport and its integration with the mass transit systems (tram and light rail), determining effects both to private and public transport.
The application of model in future scenarios by pivoting method

The method of pivoting has been used to estimate the variation of demand attracted by the various modes of transport compared to the current situation based on the scenario created by the introduction of trams, the closure of railway ring, the realization railway crossing and the reorganization of road public transport.

The expression of pivoting method is:

\[ \hat{d}_{odm}^F = \hat{d}_{odm}^A \cdot \frac{d_{odm}(T^F)}{d_{odm}(T^A)} \]

where:

- \( \hat{d}_{odm}^F \) estimated users going from origin O to destination D through the mode m, in the future scenario;
- \( \hat{d}_{odm}^A \) is the flow of people moving from origin O to destination D through the mode m, in the current situation;
- \( d_{odm}(T^A) \) is the estimation by model of users flow moving from origin O to destination D through the mode m in the current situation;
- \( d_{odm}(T^F) \) is the estimation by model of users flow moving from origin O to destination D through the mode m in the future scenario.
Outcomes

The results highlight for both scenarios an average decrease of 8% of private traffic volumes and an average increase of about 40% for transit.

<table>
<thead>
<tr>
<th></th>
<th>Short term scenario</th>
<th>Medium term scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private car</td>
<td>-7.95%</td>
<td>-8.49%</td>
</tr>
<tr>
<td>Transit</td>
<td>+48.86%</td>
<td>+40.38%</td>
</tr>
<tr>
<td>Total</td>
<td>+40.91%</td>
<td>+32.86%</td>
</tr>
</tbody>
</table>
Conclusion

1. The application of the demand model to a node of Palermo “Notarbartolo Station” has allowed to estimate the variation of transport demand on some O/D relations, produced by expected improvements of transit (tram, urban light rail, ...).

2. The application of the model on O/D relations has showed the following modal shift: an average decrease of 8% of private traffic volumes and for transit an average increase of about 40%.

3. Finally by analysis emerges a strong propensity to use public transport that should be further analyzed considering other O/D relations with gradually increasing distance from the light rail station and modal alternatives not all now available.
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Thank you for attention

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